

California Regional PM₁₀ and PM_{2.5} Air Quality Study (CRPAQS)

Statement of Work – CRPAQS Data Analysis Task 5.2 Evaluation of Transport

**STI-902329-2299-WP
Sonoma Technology, Inc.**

December 10, 2002

Introduction

Task 5.2 addresses a number of questions related to meteorological variables associated with elevated particulate matter (PM) concentrations; specifically, the transport characteristics of PM and its precursors under different meteorological conditions. This task will address the following questions:

1. What are the inter- and intra-basin winter and non-winter transport pathways in Central California?
2. How do eddy flows and the nocturnal jet influence transport paths and PM concentrations?
3. Are there well-defined pollutant flux planes between source and receptor areas during the winter, as past studies have shown to exist during the summer?
4. What is the PM and PM precursor flux through the flux planes during or on the day prior to winter and non-winter PM episodes?
5. What is the relationship between synoptic/regional meteorology and inter- and intra-basin winter and non-winter transport and fluxes and how does the meteorology influence transport distance and speed?
6. What types of synoptic/regional meteorology are associated with stagnation and little or no transport between basins?
7. Are synoptic meteorological patterns and resulting transport paths correlated?
8. Is the dispersion of PM and PM precursors dominated by advection or does diffusion play an important role (especially under low wind speed conditions)?

Scope of Work

The questions above will be addressed using two distinctly different approaches: STI will use a modeling approach and T&B Systems will carry out descriptive analyses. Close interaction and frequent exchange of information will occur between STI and T&B Systems throughout the project as many aspects of each approach rely on results of the other. In addition, STI, with assistance from T&B Systems, will integrate the results from both approaches, as well

as findings from past studies such as IMS-95 and SJVAQS/AUSPEX, to develop a comprehensive set of conclusions.

The modeling approach will involve producing diagnostic wind fields using the CALMET meteorological model. Trajectories produced from the CALMET wind fields and from ARB prognostic MM5 wind fields (if available) will be used to address transport pathways at various altitudes and locations; transport distances and times; trajectory paths and their relationship to high PM concentrations, locations and duration; the influence of nocturnal jet and eddies on transport; and the relationship between transport and general meteorological weather patterns.

The descriptive analyses include weather pattern classification; characterization of observed meteorological features such as jets, eddies, and vertical wind shears using the wind profiler data; identification of wintertime flux planes; estimates of PM flux across both wintertime and well-defined summertime flux planes; and determination of the relative influence of advection and diffusion on PM concentrations.

Technical Approach

STI and T&B Systems will conduct the work in three task elements: (1) acquire data, confirm data validity, and select episodes; (2) modeling and trajectories; and (3) analysis of model output and observational data. These activities are described below.

Task Element 1: Acquire data, confirm data validity, select episodes

For this task element, we will gather PM and nephelometer data collected during the CRPAQS measurement phase at sites within the San Joaquin Valley (SJV) air basin. Using these data, we will select up to 40 winter and non-winter PM episode days to study. The selected episodes will represent the various PM episode types, including summertime fugitive dust and secondary particulate events; early fall fugitive dust; agricultural burning and secondary particulate events; and late fall and wintertime weak fog and light wind PM events that are dominated by secondary ammonium nitrate, ammonium sulfate, and organic aerosols. The selected episodes will also include days on which transport appears to have a significant influence on PM and days on which local stagnation appears to have a significant influence on the PM. For contrast, the selection will also include some days on which PM concentrations remained low to moderate. In addition, when selecting PM episode days, we will consider various PM characteristics such as the maximum PM concentration, the duration of high PM concentrations, and the spatial extent of high PM.

For the selected episodes, we will obtain PM and nephelometer data collected at sites surrounding the SJV air basin that are useful for assessing transport of PM and PM precursors. We will also use, when reasonably obtainable, radar wind profiler and moments data, radio acoustic sounding system (RASS) virtual temperature data, rawinsonde data, and surface meteorological data at all sites with validated data within central California. We will then conduct a brief review of the data to confirm its quality for use in modeling and data analysis. Data with validity issues that cannot be quickly resolved will not be included in the modeling and subsequent analysis effort. **Table 1** shows the radar wind profiler and RASS sites that

operated during various periods of the CRPAQS measurement phase and from which we will obtain data. We will use the profiler moments and RASS virtual temperature data to estimate mixing heights and then use the mixing heights to determine when and where air parcels at different levels mix to the surface. We will also obtain and decode Eta Data Assimilation Data System (EDAS) model wind field data for the episode days. The EDAS data will be used as the “domain mean wind” in the CALMET model runs. We may also use trajectories prepared by ARB, if available.

Table 1. Radar wind profiler and RASS sites that operated during various periods of CRPAQS.

| Site Name | Site ID | Latitude | Longitude |
|----------------|---------|----------|-----------|
| Angiola | ago | 35.95 | -119.54 |
| Arbuckle | abk | 39.1 | -122.04 |
| Bodega Bay | bdb | 38.2 | -123 |
| Bakersfield | bkf | 35.35 | -118.96 |
| Carrizo Plain | car | 35.4 | -120.09 |
| Chowchilla | ccl | 37.11 | -120.24 |
| Chico | cco | 39.69 | -121.91 |
| Fresno | fat | 36.77 | -119.71 |
| Grass Valley | gvy | 39.17 | -121.11 |
| Los Banos | lba | 37.07 | -120.87 |
| Lemoore | lem | 36.27 | -119.8 |
| Lost Hills | lhs | 35.62 | -119.69 |
| Livermore | lvr | 37.7 | -121.9 |
| Mojave | mjv | 35.09 | -118.15 |
| Monterey | nps | 36.69 | -121.76 |
| Pleasant Grove | psg | 38.77 | -121.52 |
| Redding | rdg | 40.52 | -122.3 |
| Richmond | rmd | 37.95 | -122.4 |
| Sacramento | sac | 38.18 | -121.25 |
| Simi Valley | sim | 34.3 | -118.8 |
| San Martin | smr | 37.1 | -121.6 |
| Stevinson | svs | 37.34 | -120.83 |
| Tracy | tcy | 37.7 | -121.4 |
| Trimmer | tmr | 36.9 | -119.31 |
| Fairfield | tra | 38.27 | -121.92 |
| Visalia | vis | 36.31 | -119.39 |
| Waterford | wfd | 37.65 | -120.67 |

Task Element 2: Modeling and trajectories

In this task element, STI will run the CALMET model to produce the necessary wind fields for trajectory analyses. The model will be run with a fine enough horizontal and vertical resolution to accurately capture the timing, strengths, and vertical structure of the important flow features, especially those that are likely to be important for the transport and diffusion of chemical species. These include flow-through passes, eddies, the nocturnal jet, up-slope flows,

localized downslope flows, and convergence zones, as well as various meteorological patterns associated with high PM concentrations.

We will produce hourly, three-dimensional wind fields using the CALMET diagnostic wind model for the selected episode days. We will then evaluate physical reasonableness of wind fields given the geography, overall meteorological patterns, and observed air quality. The inputs to the CALMET model will consist of 1-km surface terrain height, 1-km land use data, surface, rawinsonde, and radar profiler wind data, vertical temperature profiles, and EDAS wind fields. The CALMET wind fields will be developed with 4-km horizontal resolution. The vertical structure of the wind fields will be tailored to the radar profiler range gates and will have about 22 wind-field layers with the top of the domain at about 4000 m agl. The horizontal domain will be from 40 degrees latitude north to 34.5 degrees latitude south and 124 degrees longitude west to 117 degrees longitude east, which will roughly encompass California from Point Conception north to Chico.

Using the CALMET model wind data, we will produce 72-hr back-trajectories at three or four levels on the selected winter and non-winter episode days. The levels will be chosen by reviewing vertical time-height cross-sections of wind data from selected radar profiler sites to determine the depth and elevation of various flow regimes, which include synoptic flows; regional flows such as the nocturnal jet, Fresno eddy, and the delta breeze; and local flows such as night time drainage and daytime upslope flows. We will run the trajectories from three to five locations and at various times of day and choose the times and locations based on the times and locations of high PM concentrations on any given day. We will also obtain ARB's MM5 trajectories when available for the selected episodes.

Analysis of Model Output and Observational Data

For each episode day, we will evaluate the synoptic and regional scale meteorology by reviewing the information in Task 5.1 (performed by T&B Systems) and create weather types for the episode days. We will then review the trajectories associated with each weather type to determine the relationship among the transport paths, the weather types, and PM concentrations and locations. We will group days with similar weather types and review the trajectories for each group of days to determine if the weather types and transport paths correlate. We will review the observed meteorological features such as jets, eddies, and vertical wind shears using the radar profiler wind data. We will then compare the existence, duration, and strength of these features with the calculated trajectories, weather classes, and observed PM concentrations and locations. We will create a table that summarizes these results so they can be used to support other data analysis tasks. In addition, we will provide descriptions of example trajectories that represent the different trajectory types for each weather type.

We will overlay back-trajectories for different levels that begin at the same time and location and use these plots to determine how the various flow regimes influence the trajectory paths, time, and distance. In doing so, we will note the transport pathways between the air basins and the potential for inter- and intra-basin transport at different levels within the maximum height of the planetary boundary layer (PBL). We will estimate the maximum height of the PBL by reviewing radar profiler reflectivity data and temperature soundings from selected sites for each episode day.

We will review the wind fields at various levels in the atmosphere and observational wind data to determine if there are well-defined flux planes for the winter episode days, and relate the existence or non-existence of the flux planes with the weather types. We will also determine the flux planes during non-winter PM episodes and compare those to the well-defined non-winter flux planes determined in past studies such as SJVAQS/AUSPEX. Lehrman et al. (1994) and Blumenthal et al. (1997) estimated boundary layer mass flux of pollutants (ozone and NO_x) into, within, and out of the SJV during the summer based on SJVAQS/AUSPEX measurements. Because the richness of the CRPAQS meteorological database is similar to that of the SJVAQS/AUSPEX, we will be able to estimate volume air fluxes from the CALMET wind fields. To estimate the PM and PM precursor fluxes, we will use the volume air flux estimates combined with surface air quality data. We recognize that aloft air quality data are very limited; therefore, it will be difficult to produce accurate estimates of PM and PM precursor flux through the entire depth of the PBL beyond about a factor of two. In addition, during the day when the boundary layer is well mixed, the flux estimates using the surface air quality data will probably be a better estimate of the total boundary layer flux than the nighttime flux estimates. At night, several stratified pollution and wind layers often exist, and the surface air quality data is often not representative of these aloft layers. At CRPAQS anchor sites, continuous measurements of total mass, PM precursors, and various elemental mass components were obtained. The CRPAQS satellite network includes 35 to 50 sites (differing by season) measuring b_{sp} continuously. Therefore, we will use that data set as a surrogate for PM mass based on relationships established earlier in IMS-95 and refined by other participants in this analysis. We will then investigate the relationship between the estimated fluxes of PM and its precursors and compare it to observed PM concentrations in the SJV.

We will calculate horizontal advection and diffusion terms using observational meteorological data under a range of wind speed and atmospheric stability conditions at selected sites, days, and times. The meteorological conditions will include low wind speeds and stable conditions. We will compare the relative influence of advection and diffusion. We will then create an index from +1 to -1 that summarizes the influence of advection and diffusion on pollutant movement, where +1 indicates advection-dominated cases, 0 indicates similar amounts of advection and diffusion, and -1 indicates diffusion-dominant cases. We will create a table that summarizes these results for the episode days.

We will then synthesize results from this analysis and integrate selected findings from past studies, including IMS-95 and SJVAQS/AUSPEX. A brief outline of the findings memorandum is shown below.

Introduction

- Overall CRPAQS objectives

- Relationship between overall objectives and transport analysis objectives

- State of knowledge prior to this transport work effort

Method

- Data availability and sources

- Methods to meet objectives

- CALMET modeling

- Trajectory analysis

- Descriptive analysis

Results

- Flow pathways and inter- and intra-basin transport
- Eddies and the nocturnal jet
- Flux planes and flux of PM and PM precursors
- Transport and synoptic meteorology
- Advection vs. diffusion

Discussion of results

- Transport characteristics and observed PM during winter and non-winter episodes

Conclusions and Recommendations

Task Staffing and Management

STI's overall project manager is Lyle Chinkin. The STI task manager assigned to Task 5.2 is Mr. Clinton MacDonald. He will be assisted by Don Lehrman (T&B Systems). Dr. Paul Roberts will serve as a technical advisor for the data analysis, and Mr. Neil Wheeler will serve as a technical advisor for the modeling effort.

Budget Assumptions

For budget purposes, we have assumed that the radar profiler wind data needed for this task will have been validated to a level so the data are ready for immediate use in modeling and analysis, with little or no need for further judgment regarding the meteorological reasonableness of the data. In addition, we assume that the surface meteorological data will be in one or two common formats and will be available from no more than three sources.

Schedule of Deliverables

Table 1 lists the deliverables to be prepared for Task 5.2 and their estimated delivery dates. The schedule for this task is somewhat dependent on the availability of results from other tasks. Additional time (and, potentially, resources) may be required if the products of other tasks are not received as planned.

Table 1. Estimated schedule of deliverables.

| Deliverable | Deliverable Due Date |
|--|----------------------|
| Submit final work plan | January 6, 2003 |
| Perform modeling and analyses | July 2003 |
| Prepare draft technical memorandum | August 2003 |
| Submit final technical memorandum | September 2003 |
| Submit peer-reviewed paper and conference presentation | October 2003 |

ARB Staff Assigned to this Task

The ARB Project Manager assigned to this Task is:

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Data Products to Be Performed/Delivered by ARB

ARB will supply STI with back-trajectories of specified episodes. STI will work with ARB to determine how the data will be transferred to STI and in what format(s) the data will be provided.

Software and Models to be used by STI

STI will use the following software to complete work under this task:

- Microsoft Word
- Microsoft Excel
- Microsoft Access
- ArcGIS 8.2
- CALMET

References

- Lehrman D.E., Smith T.B., Knuth W.R., and Dorman C.E. (1994) Meteorological analysis of the San Joaquin Valley Air Quality Study, Atmospheric Utilities Signatures, Predictions and Experiments Program (SJVAQS/AUSPEX).
- Blumenthal D.L., Lurmann F.W., Roberts P.T., Main H.H., MacDonald C.P., Knuth W.R., and Niccum E.M. (1997) Three-dimensional distribution and transport analyses for SJVAQS/AUSPEX. Draft final report prepared for San Joaquin Valley Air Pollution Study Agency, Sacramento, CA by Sonoma Technology, Inc., Santa Rosa, CA, Technical & Business Systems, Santa Rosa, CA, and California Air Resources Board, Sacramento, CA, STI-91060-1705-DFR, February.